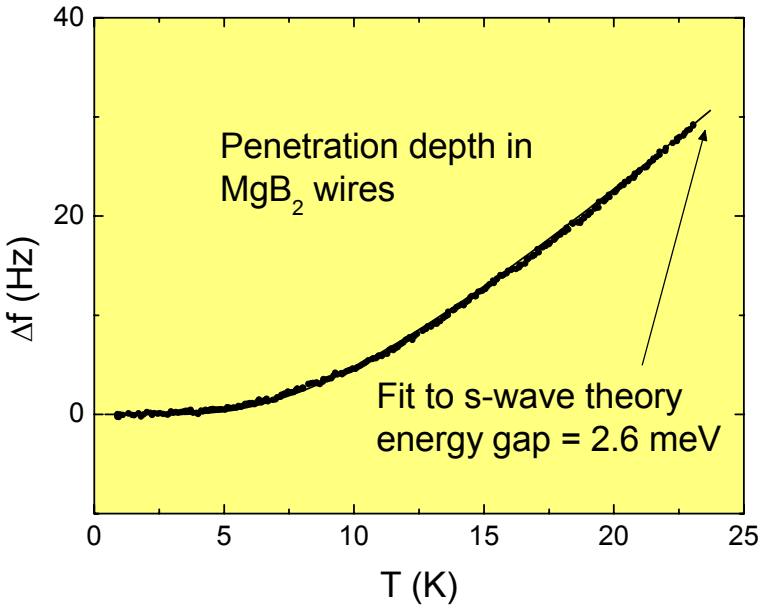
Field-Dependent Penetration Depth in Unconventional Superconductors.

Russell Giannetta, U. Illinois at Urbana-Champaign, DMR-0101872.

All superconductors tend to expel magnetic fields. The London penetration depth is a measure of how well a given material accomplishes this task. A technique developed in this lab allows us to measure tiny changes in the penetration depth of a crystal using the frequency of a low temperature electronic oscillator. We recently studied MgB_2 , which superconducts at 39 K. If MgB_2 is related to the copper oxide superconductors discovered in 1986, its penetration depth would vary as a power of the temperature, indicating "d-wave" pairing of the charge carriers. Instead, we found that the data, shown to the right, is fit perfectly by an "s-wave" theory more appropriate to low temperature superconductors like aluminum. However, the energy gap we obtained is much smaller than expected for a conventional s-wave material. This suggests the possibility of two energy gaps in MgB_2 , a very rare occurrence.



Data from R. Prozorov et.al., *Phys. Rev. B* , *Rapid Comm.* **64**, 180501R (2001)

Postdocs: Ruslan Prozorov, David Lawrie

Superconductivity and Magnetism
Page 2

The relationship between superconductivity and magnetism is a fundamental problem. To explore it, we have studied the compound SmCeCuO whose crystalline structure consists of alternating layers of superconductor (S) and ferromagnet (F), shown to the right. Such a system is predicted to undergo a transition to a "π -state " in which the superconducting quantum phase, φ , would alternate from 0 to π from layer to layer as shown. Our penetration depth measurements have uncovered strong evidence for such a new superconductive state. The lower plot shows a cusp near 4 Kelvin where spins are known to align. Unlike a purely magnetic transition, however, the temperature of this cusp is lowered by relatively small magnetic fields. This indicates that the state below the cusp is a new type of superconductor, possibly the " π - state " . Since SmCeCuO is an unconventional, copper-oxide superconductor, this development will provide important insights into the role of magnetism in the formation of high temperature superconductivity.